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RECUPERATIVE TANKS AT FAIRMOUNT GLASS WORKS

Many practical glass men ridicule the idea of the recuperative furnace as a rapid, economical means for melting glass. But Fairmount Glass has operated two recuperative tanks for more than six years and the results may be quite surprising to many practical glass men.

The history of attempts to utilize the recuperative type of furnace for the continuous melting of glass offers comparatively little evidence in favor of the practicability of this design. As a matter of fact, a great deal of the evidence is distinctly unsatisfactory and this is reflected in the fact that practically all continuous glass tanks now in operation in this country are of the regenerative type. Many plant operators will, therefore, be rather astonished to learn that the Fairmount Glass Works, Inc., of Indianapolis, is operating a couple of recuperative tanks at usual melting rates and with better-than-usual fuel consumption. In this, the first published description of the operations at Fairmount Glass, THE GLASS INDUSTRY is privileged to present the detailed history of this substantial achievement.

It is interesting to note that, at the outset, the factor which caused favorable consideration to be given to the recuperator type of furnace at Fairmount Glass was not efficiency, but simply a matter of space economy and plant flexibility. Six years ago there were certain practical shortcomings in the art of recuperator design and construction, but these were outweighed by the more immediate problem of space utilization and an improved design of recuperative furnace was chosen. The recuperators now in operation at Fairmount Glass are quite different in detail from the original installations, improvements and changes having been made at intervals during the intervening 6½ years until these furnaces now represent probably the most dependable and economical glass-plant application of the recuperative furnace.

Cooperation Between Builder and Operator

The achievement results from a fortunate combination of glass plant executives with foresight, patience and discernment, and a furnace builder with a sense of responsibility and a spirit of cooperation. Both John H. Rau, president, and Charles D. Rau, treasurer of Fairmount Glass, together with their operating staff, have exhibited a keen interest in the operation technique and technical development of these furnaces and have a thorough understanding of the problems involved. The Amsler-Morton Co., of Pittsburgh, which designed and built the furnaces, has also been alert to solve the problems of design and construction as they have arisen. The outcome of these cooperative efforts reflects great credit on both organizations and is, without doubt, an important contribution to the art of recuperative tank design and practice.

The manufacuring processes at the Fairmount Glass

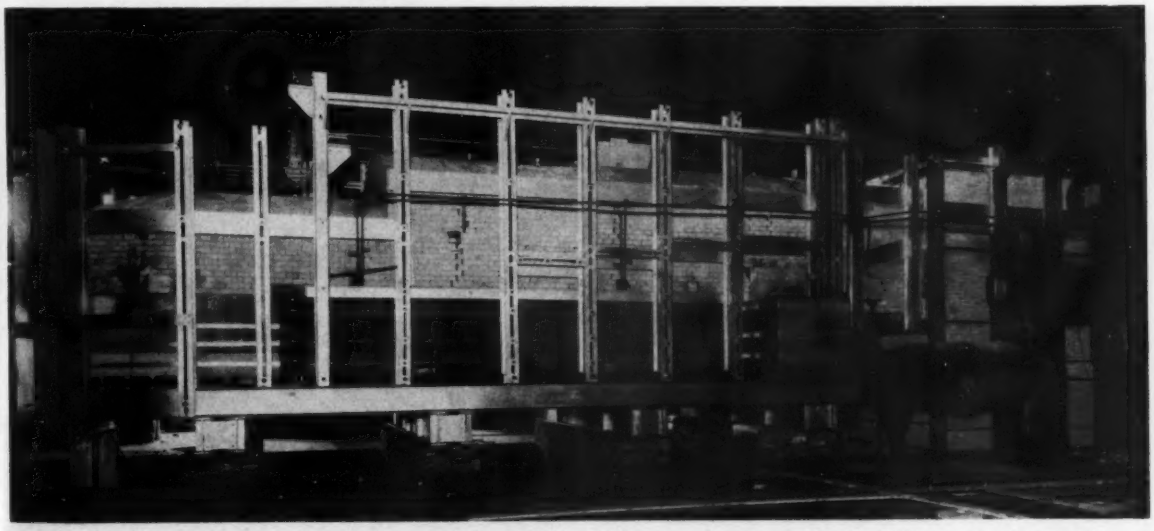

Fig. 1. No. 1 recuperative tank at Fairmount Glass Works, during warming-up period in 1932. The photograph was made from the site of No. 2 tank which was built in 1933. The recuperator housing is at the extreme right and the gas flue can be seen passing transversely under the port. See Fig. 2 for construction details.

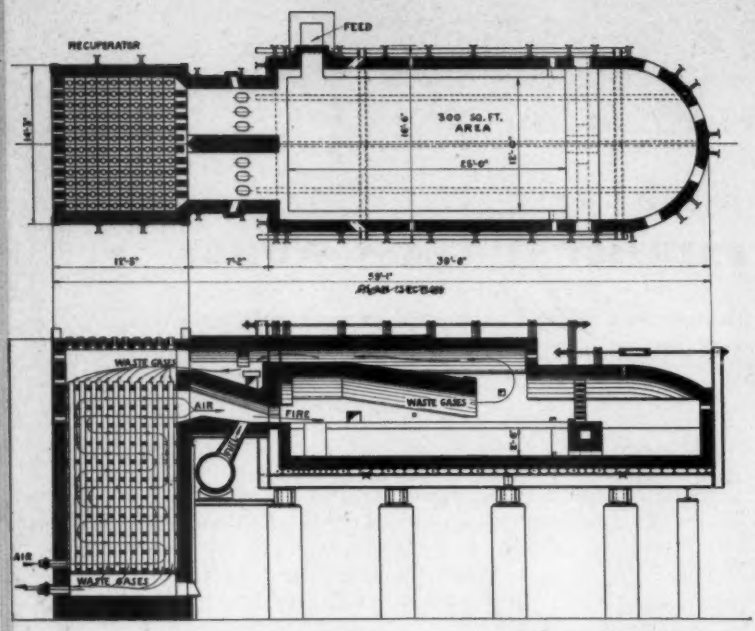

Fig. 2. Longitudinal sections through No. 1 recuperative tank in its present form, showing elevation below and plan above. Arrows indicate the path of combustion air, fuel and waste gases. Note particularly the double-crown construction above the melting end of the tank.

Works are carried on in two factories, designated No. 1 and No. 2, in each of which, prior to 1932, a regenerative tank was located. The tank in No. 1 factory was used mostly for amber glass, but in 1931 the call for this product had decreased to such an extent that the furnace could not be operated economically. Therefore, in order to provide a similar furnace for amber and to secure additional production facilities for flint, it was planned to replace the regenerative amber tank with two smaller tanks, one for amber and one for flint. The Amsler-Morton Co. was called into consultation, but after a thorough study it was found impossible to house two cross-fired regenerative tanks in the No. 1 factory building. These insurmountable space limitations practically forced the consideration of the recuperative type of furnace, since no other design could be fitted in, and a contract for the construction of one furnace was given to Amsler-Morton, after a thorough study of other installations and careful consideration of suggested construction and improvements.

Construction was started early in 1932 and the new tank was placed in operation on amber glass in May of that year. Fig. 1 is a view of the new tank during the warming-up period and it will be described in detail later. It is referred to as No. 1 tank. In July, 1932, the new tank was changed over to flint glass and alternate runs of amber and flint were made until March, 1933, when operations were suspended after a campaign of 10 months. At the end of this campaign the condition of the tank and its operating record were carefully examined by the operator and the builder and the construction of the second tank alongside the first was authorized. No. 2 tank was put into operation on flint glass in July, 1933, and its first campaign lasted for 16 months. No. 1 was also rebuilt and started up again on amber glass the same summer, its subsequent campaign having a duration of 18 months.

During the ensuing years both tanks have been operated on flint and amber glasses as required. The present campaign on No. 2 tank was started early in 1937 and the current campaign on No. 1 tank began about six months later. During all of this time the regenerative No. 3 tank in No. 2 factory has been in operation on flint glass and although it is considerably larger than the others, its operation has provided a basis of comparison between the regenerative and recuperative systems in the same plant. No. 3 tank was completely rebuilt by Amsler-Morton in 1934 and its fuel consumption rate is better than average. It has six ports on each side; the melting end is 38 ft. long by 21 ft. 8 in. wide; the refining end has a radius of about 11 ft. 3 in. and serves eight bottle machines. All three tanks are operated on producer gas, each factory being furnished with a battery of three Duff hand-poked producers.

Both of the recuperative tanks are identical, except for size, the major dimensions being as follows:

	Melting Area			*Floor Space*	
Tank	*Width*	*Length*	*Sq. Ft.*	*Length*	*Width*
No. 1	12 ft.	25 ft.	300	60 ft.	17 ft.
No. 2	14 ft.	29 ft.	406	70 ft.	21 ft.

In each furnace the tops of the side-wall blocks are 8 ft. 4 in. above the factory floor. The construction details are clearly shown in Figs. 1 and 2, which illustrate No. 1 tank.

Recuperator Construction and Combustion Cycle

The salient features of the Fairmount recuperative tanks are the double crown in the melting end and the special design of the recuperators themselves. It will be noted that the recuperator housing is located at the rear of the melting end and extends beneath the factory floor, where the clean-out doors are located, together with the steel flues for the incoming combustion air and the outgoing combustion products. These details are shown in

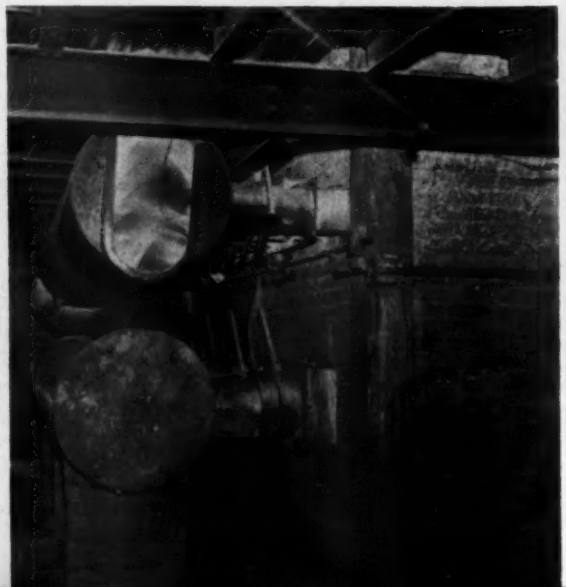

Fig. 3. Bottom of No. 2 recuperator housing in the basement. The top flue at the left handles incoming combustion air under forced draft. The bottom flue conducts the waste gases from the recuperator and is connected to an exhaust fan.

Figs. 3 and 4. The incoming air rises through the recuperator in a tortuous path, between baffles and in contact with the outside of the hot recuperator tubes.

Near the top of the recuperator the heated air flows into a passage leading to the burner port, the gas flue being located beneath this passage between the back end of the tank and the recuperator housing, as shown in Fig. 5. Fuel gas and air are mixed in the passage and emitted through the burner port into the melting end of the tank. The burning fuel and products of combustion then flow toward the front end of the tank beneath the inner crown to a point a few feet back of the bridge wall, then upward through a large opening in the crown and finally backward again between the two crowns toward the top of the recuperator. From the space between the top baffle wall of the recuperator and its roof, the combustion products enter the vertical tubes and pass downward to the outlet space and flue at the bottom.

This simple cycle has certain advantages from the standpoints of heat-transfer efficiency and combustion. It is apparent that, after operating conditions have been secured, all parts of the system remain at reasonably constant temperatures, since there is no reversal of the gas flow at any time and each section is always subjected to the same conditions of temperature and combustion. Second, the arrangement of the recuperator provides the true counter-current principle of heat transfer, in which the coldest air meets the coldest products of combustion at the bottom and the hottest air and hottest gas meet at the top. This results not only in a relatively large transfer of heat between the outgoing gas and the incoming air, but also in a relatively high air temperature at the port. Temperature differentials through the recuperator tubes are also held at a minimum. With tank crown temperatures at from 2,600 to 2,700 deg. F., air temperatures as high as 2,000 deg. F. in the port are said to be usual.

Since the entrance port for the fuel mixture functions only as a burner and never as an exhaust opening, it can be proportioned for the single function only and combustion and flame control is thereby enhanced. The use of the double crown, in which the bottom of the inner crown is subjected to the heat of combustion while the top is heated by the outgoing combustion products, worries a good many practical glass makers, but these qualms seem to be unfounded, since no trouble from this construction has been encountered. Furthermore, since the inner crown is able to maintain its integrity under operating conditions, it is apparent that the double-crown construction must act as a heat conserver and have a definite effect on the heat efficiency of the furnace.

The fact that Fairmount Glass has continued to operate these recuperative furnaces for more than six years, as well as the decision to build the second furnace after a 10-months campaign with the first, indicates that the difficulties encountered have been of a relatively minor nature, although they had to be surmounted if the installation was to be commercially practicable. The history of the problems that came up, and the means taken to solve them, is most interesting. Some of these problems are found in any tank construction and are not particularly pertinent to this discussion, but those arising from the use of the recuperator deserve careful consideration, because the present satisfactory construction and operation have resulted in a large degree from the measures taken to overcome the difficulties as they appeared in actual practice.

Fig. 4. Front view of No. 1 recuperator housing in the basement, showing clean-out doors. Debris from the inside of the tubes falls to the bottom of the recuperator and is easily removed through these doors.

Operation Difficulties Eliminated

Some of the first changes necessary were in the burner port and passage. The ports were originally made from a plastic-formed chrome mixture which softened into a tough, viscous mass, causing the port to change in size and shape. The difficulty was overcome by using refractory stone for the port blocks. Also, the openings through which the gas enters the air passage from the flue were originally provided with hoods on the side toward the incoming air, but these were later removed to give better mixing of the air and fuel in the passage. Some changes were also required in the size and position of the ports in the flint tank, in order to produce the best combustion conditions. With these minor changes, the burner ports and passages stand up well in service and function very satisfactorily.

The crowns of the recuperator housings are of the suspended-arch type and one of these fell in at one time, causing a lot of trouble. The occurrence was, however, purely accidental and could not be charged against the recuperator practice. These suspended recuperator roofs are still being used and have given excellent service.

As might be expected, most of the troubles in the recuperator itself have been caused by cracking and clog-

Fig. 5. Closer view of the right side of No. 1 tank. Recuperator at left; entrance port in center with gas main below; melting end of tank at the right.

ging of the recuperator tubes. The clogging is the most important and has been the principal reason why the recuperator still remains under a cloud in some quarters. But clogging has been pretty thoroughly eliminated at Fairmount Glass, through some very sensible cooperation between the glass company and the builder.

The tubes furnished in the original recuperators were 5 in. square, inside, with slightly rounded corners, and the tops of the tubes were flush with the upper surface of the top course of baffle tile. After a period of operation the drip from the roof of the recuperator, together with the flux from the furnace, began to form a viscous mass on the top of the baffle wall and this gradually ran over the edges of the tubes. Then it began to build out in a shelf-like projection which, unless removed, soon restricted the tube opening seriously. However, it was almost impossible to remove the tough, viscous masses at the top edges of the tube openings. It was recognized that the formation of the viscous mass on the upper surface of the tile and its subsequent flow into the tube opening was causing the trouble and the problem was solved by placing a short thimble over each tube opening. These stub tubes, or thimbles, can be seen in Fig. 2. They project about 4 in. above the surface of the tile and have practically eliminated clogging at this point.

However, there still remained a tendency to clog at the flux condensation point part way down the tubes. Accretions on the sides of the tubes could be loosened by tools introduced through the clean-out holes in the recuperator crown, but it was difficult to get the deposit out of the corners, where a shelf-like projection would build out and secure support from the adjacent sides of the tubes. Various means, including rifle bullets and shotgun slugs, were used to dislodge these corner deposits, but they were never entirely successful and the accretions slowly encroached on the tube openings until the efficiency of the recuperator was seriously affected and a major repair was finally necessary. As a matter of fact, the clogging at this point remained one of the factors limiting the length of the heating campaign until last year.

Development of Cylindrical Tubes

After thorough study and consideration of the cleaning and operation of the recuperator tubes, Mr. Charles Rau suggested that the troublesome corners be eliminated by the use of larger tubes with a cylindrical shape. Amsler-Morton made a study of this proposal and finally produced a tube with an inside diameter of 7 inches, in which the area for waste gas travel was increased by about 50 per cent without decreasing the heat-transfer area. The new tubes were installed in both recuperators in 1937. They are cleaned at regular intervals by introducing a special tool, resembling a sash-weight with excrescences, through the crown openings and passing it up and down through the tubes by means of a chain and pulley. This simple cleaning method has been found entirely effective in obviating clogging difficulties.

Failure of tubes through breakage in service has apparently never been considered a major difficulty in the Fairmount recuperators, although some breakage has occurred. The resistance to breakage depends, of course, on such factors as the design of tube, the material and the method of manufacture. All of these factors have been subject to almost continuous experimentation, development and improvement by the builder. The circular tube provides a more stable design and the material now used has a coefficient expansion of 24×10^{-7} in. The cold modulus of rupture is about 2,400 lb. and the tubes are fired at 2,550 deg. F. In the upper two or three rows of tubes, Corhart material has been found very satisfactory. As a result of these developments, tube breakage is largely the result of cleaning operations and has now become a minor difficulty. A cracked tube cannot be replaced, of course, so the regular procedure is simply to plug

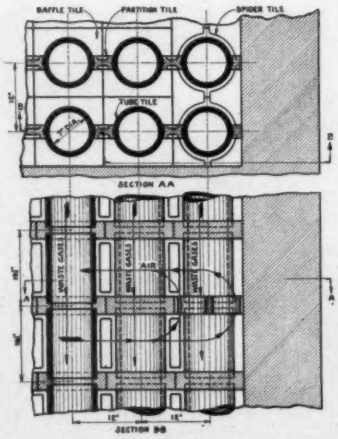

Fig. 6. Detailed construction of the recuperator, showing arrangement of tubes, baffles, partitions and "spider" tiles. Note that tube joints are in horizontal plane, held tight by weight of materials.

the defective tube at top and bottom and continue operations without it.

Recuperator Details

The detailed construction of the recuperators now operating in the Fairmount Glass Works tanks is shown in Fig. 6. The tube sections have an inside diameter of 7 in., a thickness of about ¾ in., and a length of 18 in. These sections are arranged vertically on 12-in. centers between tile floors or baffles, and partition tiles are located between the tubes so that the incoming air flows down a passage between adjacent rows of tubes. At the proper points in the ends of the passages the baffle tiles are cut away to form "spider" tiles, through which the air passes from one baffle space to the one next above, as shown in Figs. 2 and 6. It will be noted that all the joints between the ends of the tubes and the baffle tiles lie in a horizontal plane, so that the weight of the materials tends to keep the joints tight.

In these furnaces no natural draft is used. The combustion air is furnished by forced draft fans, the fan for the smaller tank being driven by a 2-hp. motor and the other with a 3-hp. motor. Larger fans of the induced draft type are connected to the waste gas flues and draw the combustion products out of the recuperator. These fans represent equipment not needed with the usual type of regenerative tank, but their installation cost is probably offset by the elimination of stack, brick flues and reversing valves.

The doghouses for charging the tanks are located at the side of the melting end near the back, each doghouse extending into the center aisle between the two tanks. Fig. 7 is a view down this aisle from the recuperator end of the installation, showing the gas piping to No. 1 tank and the doghouse in the background. The illustration on the front cover shows the other side of No. 1 tank looking toward the recuperator housing at the rear and illustrates how the sides of the tank walls are exposed to the surrounding air.

It has been found that in these furnaces comparatively little block cooling air is needed, because of the exposed location of the blocks and the fact that they are not covered and partially enclosed by ports, port necks and checker chambers. As a matter of fact, the elevated and exposed position of these tanks places them in the path of prevailing cross drafts through the factory building and this condition tended to over-cool the working ends, particularly at low rates of pull. This tendency to overcool was overcome by insulating the side-wall blocks of the refining end.

Recuperators vs. Regenerator

Due to the more-or-less developmental nature of the operation of the recuperator tanks and the changes that have been made from time to time, it has not yet been possible to make a thorough comparison between them and the regenerative tank No. 3. The present campaign will be very informative and should provide data of a most interesting nature. However, there is already considerable information available from which to evaluate the practicability of the recuperative design. One interesting feature is that the operating men consider the temperature control on recuperative tanks more "touchy" than No. 3 and state that they have to be watched closer.

Fig. 7. Looking down the aisle between the two recuperator tanks. The recuperator and gas piping for No. 1 tank is at the right, with the doghouse and batch feeder just beyond. Corner of No. 2 recuperator appears at extreme left.

This condition may be due, however, to the methods of gas control. The producer steam pressure is held constant by a regulating valve and a mushroom valve is located in the gas line to each tank. Individual control is rather difficult, therefore, because a change in the amount of gas fed to one tank will automatically affect the fuel supply to the other.

As stated at the beginning of this article, the main controlling factor in the original selection of the recuperative tanks for this installation was the economy of space, but it now begins to appear that these furnaces can also give a good account of themselves from the important standpoints of maintenance cost, melting rate and fuel consumption as well. The following figures indicate the capacities and melting rates of all Fairmount tanks:

Tank	*Melting Area in sq. ft.*	*Tons of Glass Melted per Day*	*Melting Area per Ton*
No. 1 (recuperator)	300	40*	7.5
No. 2 (recuperator)	406	55*	7.4
No. 3 (regenerator)	823	125	6.5

Superintendent John Sweeney of Fairmount Glass Works, who has been closely in touch with the entire

*These figures represent ordinary pull on the tanks. Maximum rates have run up to 45 tons on No. 1 and 60 tons on No. 2, equivalent to melting areas of 6.7 and 6.8 sq. ft. per ton, respectively.

operation and development procedure, expresses the opinion that the recuperator tanks in their present form can be expected to produce a fuel saving of from 5 to 10 per cent over No. 3, and this opinion seems to be fairly conservative in the light of results already obtained. For a complete operating cost comparison, of course, the additional power for the draft fans must be charged and the smaller amount of power for block cooling must be credited.

All in all, Fairmount Glass Works executives are not yet convinced that the recuperators are going to melt glass right along at lower cost. But they do believe that recuperative operation is thoroughly practical and that their original objective of greater plant flexibility, in a small space and without excessive costs, has been attained. When the comparatively small size of these tanks is considered, it is certain that the results obtained are, at least, quite out of the ordinary. Their further operation will be watched with much interest by all concerned.

LITHIUM IN GLASS AND CERAMICS

In *Foote-Prints* for July, 1938, Dr. Eric Preston, of the Sheffield Department of Glass Technology, presents an extended article on the applications of lithia.

The author calls attention to the low equivalent weight of lithia, to its resemblance to the alkaline earth oxides more than to the other alkalies, and to the comparative ease of decomposition of lithium carbonate indicated by a decomposition pressure about six times as high as the decomposition pressure of sodium carbonate at 1000°C.

Among the technical papers on lithia which are cited and partially reviewed, a number of phase-rule diagrams are shown which indicate somewhat similar separate silicates and eutectics with lime silicate to those which are found in the soda-lime-silica system. Although the actual melting temperatures are about the same as in the soda systems, it appears that the glasses containing lithia have much lower viscosities. Moreover, because of the very low equivalent weight of lithia, equal percentage additions to glasses result in mixtures of lower viscosity than the corresponding soda glasses. Herein rests the advantage of using lithia for special purposes, which has been taken advantage of by Taylor and also by Waterton and Turner in some experimental glasses.

The principal natural sources of lithia are in the minerals amblygonite, a complex lithium aluminum phosphate; spodumene, a lithium aluminum silicate; and a lithium aluminum fluo-silicate known as lepidolite. None of these can be obtained commercially with a greater lithia content than about 8 per cent, and the lithia is accompanied in all three by alumina, so that the quantity which can be introduced into glass in the form of these minerals is definitely limited. However, it has been found entirely practical to produce lithium carbonate, albeit at some cost, which the writer points out will undoubtedly become lower as larger quantities of lithia find application.

In ceramics, notably in whiteware bodies, interesting results are being obtained with the direct use of spodumene, and to some extent, lepidolite, in place of feldspars.

Dr. Preston points out that as a result of iow combining weight and strong fluxing properties which require comparatively little lithia for the replacement of soda or potash, glazes and glasses of high durability or resistance to weathering can be produced. Needless to say, these applications all depend for their economic feasibility upon the production of relatively pure lithium salts, particularly the carbonate, in suitable quantity and at favorable prices.

Another interesting application of lithia is in glazes, where it may be substituted for lead oxide, thus avoiding the loss of lead oxide by volatilization, and also establishing a better condition from the standpoint of the health of the workers. On this point reference is made to research papers and, in fact, all of the material presented in this paper is well authenticated by references to the literature of glass and ceramics.

From the standpoint of glass technology, perhaps the most interesting effect of substituting lithia for soda or for potash is the progressive and relatively great reduction in working and annealing temperatures; another effect is the definite increase in the thermal expansion as lithia replaces soda molecularly; and finally, it appears that glasses high in lithia have better transmission for ultraviolet light.

Because of these interesting facts, it is to be hoped that suitable supplies of lithia may be made available at prices which will be at least justified by the improved properties of the glass and ceramic products to be made. —S. R. S.

A. S. M. E. MEETS THIS MONTH

The 59th Annual Meeting of the American Society of Mechanical Engineers will be held at the Engineering Societies Building, New York City, Dec. 5-9, 1938. Technical sessions will cover the many specialized fields in which the 17 divisions of the society are interested and a business meeting will be held on Monday afternoon, December 5th. Honors night will be on Tuesday evening and the annual dinner will occur on Wednesday evening. Major General William H. Tschappat, formerly Chief of Ordnance of the U. S. Army, has been elected an honorary member of the society.

The art of machining glass. Here a metal-glass seal is being made with the aid of a lathe. The operator is welding a glass tube to a metal tube as a step in the construction of x-ray apparatus. Photograph, courtesy Westinghouse.

THE ROLE OF GASES IN GLASS: IV. MISCELLANEOUS GASES

By W. WEYL and A. G. PINCUS
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Sulphur Dioxide

So far we have considered the interaction of gases with the glass batch and melt during the melting process. However, gases can also react with glass after it has reached a rigid condition as in the annealing furnace between the glass surface and vaporized compounds of sulphur.

In the old types of gas-heated lehrs the glass became covered with a white dust, which was proved to be the product of the action of sulphur gases from the fuel on the alkali of the glass. Incidentally, it was found that the glass surface had improved chemical durability as a result of this leaching of the alkali. At the same time the appearance of the white dust was used as a proof that the glass was well-annealed, for it indicates that the glass has reached a temperature high enough for the sulphur gases and the surface alkali to react in the time available. We will see later that some glasses undergo this reaction much below annealing temperatures.

The process which actually takes place at the glass surface is analagous to Hargreave's Process, in which the reaction between sodium chloride, sulphur dioxide, and oxygen is used to make hydrochloric acid and fix the sulphur content of gases in the roasting processes. Like sodium chloride, sodium silicate can react with SO_2 and O_2 to form the soluble sodium sulphate. When the same reaction takes place in the glass tank, it may cause trouble. Sulphur dioxide in the presence of oxygen may react with the molten glass to form "glass gall," that is, fluid sodium sulphate on the melt's surface. This trouble can easily be avoided by changing to a slightly reducing atmosphere, which immediately decomposes the glass gall already formed.

Although there is only a very loose relationship between annealing and reaction with sulphur dioxide, serious trouble has started when certain plants changed over to electric annealing furnaces. The use of this indicator even went so far that additional burning of sulphur was used for determining the proper heat treatment. Today, improved temperature measuring devices make such a guide unnecessary. Still the use of sulphur for beneficiation of the glass surface remains of interest.

Takats has studied the reaction of sulphur dioxide with various sodium silicates in the glassy and crystallized states. It is remarkable that these reactions between gas and glass start at temperatures which are far below the softening range. A few examples are given to show how far such reactions can go. Five liters of air containing 5 per cent by volume of SO_2 were conducted over powdered glasses of the given compositions at six temperatures between 300° and 500°C. The figures given in the table indicate the percentages of reacted material after two hours' treatment.

Glass	*% SO_4 Conversion at Temperature of*					
Composition	*300*	*350*	*400*	*450*	*500*	*550°C.*
$Na_2O, 2SiO_2$	8.94	12.17	22.73	48.36	54.25	60.93
$Na_2O, 3SiO_2$	5.51	4.28	4.96	4.79	5.22	5.25
$Na_2O, 4SiO_2$	2.94	3.07	3.65	3.60	3.73	2.90

In addition to sulphur dioxide, volatile forms of boric oxide, such as its hydrate or organic compounds, like methyl and ethyl borates, can be used to increase the acidity and consequently the chemical resistivity of the glass surface. There are also compounds which can split off P_2O_5 when heated, so that phosphoric acid can also be used, either in the form of its esters or in the form of an aerosol of free P_2O_5, for surface treatments. Experiments in this direction have proved very encouraging.

Adsorption, Diffusion, Solution

To pass from solution within the glass to its surface and then into the gaseous phase, or conversely to condense from the gas phase and enter into the interior of the glass, gases must go through two processes, adsorption and diffusion.

The picture, now taking shape, of the reactions between gases and solids involves a series of overlapping phenomena: first, physical or chemical adsorption of a monomolecular layer of the gas on the solid's surface; then, transportation of the gas molecules from ion to ion within the solid; and, where the gas finds some constituent of the solid to which it is attracted strongly enough, the definite solution of the gas.

Much work has been done on the adsorption of gases and water at glass surfaces because of its great importance in the manufacture of electric light bulbs and of vacuum tubes for radio and other electronic purposes. The gases are so firmly bonded to the surface that high vacua and temperatures up to 400°C. are required to remove them completely. A simple experiment will illustrate the stability of these adsorbed films. When we break a piece of glass and breathe on the fresh surface, a thin film of water molecules is condensed on the glass surface. As the refractive indices of the water and of the glass are widely different, particularly with heavy lead and barium types, the surface shows Newton's interference colors. After the glass, however, has been allowed to stand for a while in the atmosphere, this phenomenon cannot be observed any more. Instead of the clear glass surface with its high index of refraction and reflectivity, we now have to deal with the gradual transition from hydrated silica to the dense portions of the inside. This may explain the observations of Kollmorgen and of Ferguson and Wright that the reflectivity of optical glasses can be considerably decreased by a surface treatment with solutions of weak acids and salts.

Diffusion of gases through glass is also of increasing importance, although both the scientific background and the technical applications are still in primitive stages of development. The process is certainly much more complicated than a simple squeezing of the gas molecules through the holes in the random network of the glass. A certain degree of interaction between the molecules of the gas and the glass must be assumed to explain the experimental data. One of the most surprising facts which has been brought out by recent researches is that the rare gas, helium, diffuses through glass much more rapidly than does hydrogen. Taylor and Rast, for example, found that at 512°C. the rate

of helium diffusion through Pyrex is 45 times faster than that of hydrogen. The belief that the intermolecular forces have a greater bearing than the size of the spaces between the glass-forming atoms on diffusion rates is further strengthened by their demonstration that the diffusion of helium through a quenched glass is slower than through the same glass after it has been annealed despite the fact that in the quenched glass there are larger spaces between the ions.

The actual determination of the rate of diffusion of a gas into a glass can be carried out only at reasonably high temperatures where the speed is rapid enough to produce measurable pressures. In lower temperature ranges color indicators can be successfully used to study the actual depth and rate of penetration. For determining the diffusion of oxygen into glass, the manganese ion has proved a sensitive indicator. For hydrogen a special method has been worked out which is based on the fact that glasses containing small percentages of silver become fluorescent when the silver ions are converted into neutral silver atoms.

Fluorescent Glasses

Such laboratory curiosities may eventually lead to important technical applications, for they provide a means of preparing certain substances in the extremely fine-grained, molecular distribution which is essential for strong fluorescence effects. Besides silver, cadmium sulphide, selenides, and certain other substances can provide this kind of fluorescence. The principal need is to so isolate their molecules that each is free to emit the absorbed energy as light instead of having it turned into heat. In glasses the problem presents itself in much the same way as the control of grain size in certain opaque illuminating glasses. Controlled grain size can only be obtained when the two processes of nuclei formation and the growth of crystals by diffusion can be restricted to different temperature regions.

Taking cadmium sulphide glasses, for example, it is difficult to prevent the growth of cadmium sulphide aggregates to such sizes that fluorescence properties are not decreased or lost. By quenching it becomes possible to get a certain fluorescence due to cadmium sulphide in molecular distribution. If cadmium sulphide, however, could be obtained in a glass in such a short time or at temperatures where formation of larger nuclei is prevented, the intensity of its fluorescence could be increased. Instead of using a cadmium sulphide containing glass, a glass containing cadmium ions and sulphate ions may be treated with hydrogen to form molecular cadmium sulphide. The same process may be applied to the formation of zinc sulphide and other sulphides and selenides.

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Fig. 1. An unposed action shot of one of the workers at work.

CHRISTMAS TREE GLASS

Glass ornaments for Christmas tree decoration fall in the category of familiar things whose manufacturing processes are not well known. This article tells how the Heidt Ornament Co. established an old-time artisanship in this country and of its efforts to compete with imported European products.

What would the Christmas tree be without sparkle and glitter? Neither the old-time candles, nor the more modern electric lighting systems, are sufficient to produce completely that shimmering, scintillating effect which is the goal of every amateur and professional decorator, so they must needs be enhanced by the reflecting surfaces of the now-familiar glass ornaments, in every shape, size and color. For many years the most popular type of ornament has been the colored glass ball, with its shiny reflecting surface, but many other novelties of all sorts are available, as every one knows.

Until recent years practically all blown glass ornaments used on American Christmas trees have been imported and most of them have come from Bohemia, more recently Czechoslovakia. In 1935, after a lapse of several years, the manufacture of such ornaments was begun again in the United States by the Heidt Ornament Co., 1609 DeKalb Ave., Brooklyn, this company being for some time thereafter the only manufacturer of this type of glassware in this country. The recent trade agreement with Czechoslovakia has hindered the efforts of the company to compete with the European manufacturers, necessitating changes in the product, but this will be taken up later.

The name of Heidt has been connected with the manufacture of colored glass and specialties in Brooklyn for nearly 60 years. The business was started in 1879 by Louis Heidt, grandfather of the present proprietors, who came to America in 1876 from Alsace-Lorraine and commenced making opalescent and colored glass for churches, art glass and lighting ware, etc., for Tiffany and others. By 1889 the glass produced by Louis Heidt in his little Brooklyn plant had become famous the world over and he was the proud recipient of the Gold Medal for art glass at the Paris Exposition. At the death of Louis in 1902, the business was continued by his son, John B., but the son survived his father for only two years and, during the following decade, the company was operated by John's widow. Since 1914 her sons, John B. and his brother Louis, have carried on the business.

Due to the contraction of the market, the manufacture of cathedral glass was discontinued shortly after 1914 and the efforts of the young proprietors were turned to the production of novelties and specialties, including a wide variety of table decorations, candle-holders, indirect lighting ware and other items. Importations of tree ornaments ceased during the world war and it is said that in 1918 there were 10 ornament-making shops in New York, all of whom had been importers. These shops employed a total of about 1,000 people, but importations started coming in again after the war and by 1922 all of the shops had closed and the proprietors had gone back to importing. This state of affairs continued until after the devaluation of the dollar in 1933, when the Heidts decided that conditions were such that they could compete with the European products, even on the basis of 1918 costs.

The shop on DeKalb avenue was, therefore, fitted up for the making of tree ornaments, utilizing 2,300 sq. ft. of floor space, and 23 blowers with about 50 helpers were employed. The analysis of the business situation was accurate and the business grew until, in the latter part of 1937, over 50 blowers and 75 helpers were employed and some 30,000 sq. ft. of space was occupied. During this period of growth the company experimented with automatic equipment for blowing the glass balls, but the machine was never successful commercially, the big difficulty being the very narrow shoulder required on

Fig. 2. A specially built lehr 52 inches wide and 47 feet long. It has a wire mesh belt.

these items. So the manufacture of tree ornaments has remained a matter of purely hand production.

But the growing business nearly came a cropper when the Czech trade agreement of 1938 went into effect, the outcome being that the manufacture of colored Christmas-tree balls in competition with the foreign product could not be continued profitably. Casting about for something to bolster up their rapidly waning business, the Heidts found partial salvation in that invincible octet—Snow White and the Seven Dwarfs. The balance of this article gives the details of how glass, paint, etc., are combined to make this famous young lady, with Dopey and the rest, ready to grace Christmas trees for American youngsters. The technique described is practically the same for all types of tree ornaments.

The complete production line for the manufacture of a glass dwarf is shown in Fig. 1, this being an unposed action shot of one of the blowers at work. The raw material is seen to be glass tubing, here being manipulated by the blower's left hand, the equipment including a set of three gas burners and a metal mould. The burners are arranged to impinge on the tubing from both sides and below, the mould being of the split type, normally held open by a spring and closed by means of a foot-pedal.

The celerity with which a skillful blower changes the prosaic tubing into perky little Grumpys or Sneezys is quite amazing. As one figure is being blown, the tubing is held in the flame at the point where the next blank will be separated and the newly blown figure is then held in the flame a few seconds for partial annealing. Almost immediately the tubing is ready for separating another blank and a long pigtail is drawn out as the separation is made. The pigtails are important, because the ornaments are handled by them throughout manufacture and they also provide the means for finally hanging on their ultimate resting place, the Christmas tree.

As soon as the blank is separated, the hole in the bottom of the bulb is closed in the flame and the blank is heated and manipulated in the blower's right hand until it is ready for blowing. Then it is clapped into the mould, the mould is snapped shut with the pedal and the blower proceeds to change himself into a compressed-air machine, as shown in the photograph.

Although the blown ornament is partially annealed in the fire by the blower, this is simply done as a precaution, so that the thin glass will not immediately fly into pieces. Each piece is subsequently annealed in a gas-fired lehr, the discharge end of which is shown in Fig. 2. This specially-built lehr is 52 in. wide by 47 ft. long and has a wire-mesh belt. A motor drives the belt through a speed reducer and a Reeves transmission. Annealing results are carefully checked by a polariscope which is mounted for convenience on a portable table.

The shiny appearance of tree ornaments is produced by an inside coating of silver and this operation is illustrated in Fig. 3. The operators at the left draw about 3 c.c. of silver nitrate solution into each ornament from the containers above and the pieces are then passed to the girls at the other side of the table, who add about one dram of sugar solution to act as a developer. The pieces are shaken up a little to coat the glass with solution and are then plunged into a tub of hot water for a few seconds. Then they are placed on a rack to drain. The water is heated by a gas burner and is held at 160 deg. F.

Fig. 3. This illustration shows the inside coating of Christmas tree ornaments with silver, which gives them their shiny appearance.

by a thermostat. In the drain rack about 12 per cent of the silver nitrate solution is recovered.

The silvered ornaments are next dipped into colored, transarent, non-streaking lacquer and dried, this process being illustrated in Fig. 4. Here in the foreground can be seen a tray of silvered dwarfs. The operators dip the glass pieces in the lacquer and place them on holders on the continuously-moving conveyor of the electric drying oven in the background. The drying operation takes about 14 minutes and the temperature in the oven is automatically controlled. For the silvered ornaments red, blue and green lacquers are used.

Snow White and Dopey, being the outstanding members of this group, are given a different decorative treatment than the rest, neither one of which requires silvering. The young heroine's final appearance must, of course, be snow-white and this is accomplished by a dip into opaque white enamel. Dopey's final complexion is pure gold, in appreciation of his sterling qualities, perhaps, and his coating of gold enamel is applied with a spray gun, as shown in Fig. 5. After drying, the pigtails are removed from the ornaments and the little metal caps and spring loops are added. Then a final inspection and the little images are packed in boxes in sets.

But, after all, Snow White and the dwarfs can hardly put the Heidt business back on an even keel again, because they are produced by only one-third of the persons employed in the shop last year. The implications of the situation are of general interest, as well as of immediate interest to the little Heidt Ornament Co., because many of the sociological trends of recent months are here on a small scale. First, the small business man can be seen as he tries to hold his own against conditions beyond his control; second, the impact of the trade agreement upon the competing American manufacturer is illustrated on a small scale; and third, the unemployment question is again raised when two-thirds of the working force are laid off necessarily in the middle of a general business depression. The present European turmoil will probably have a reaction at Heidt's, but is still too early to predict the effect.

Fig. 4. The silvered ornaments are dipped into colored non-transparent non-streaking lacquer and dried.

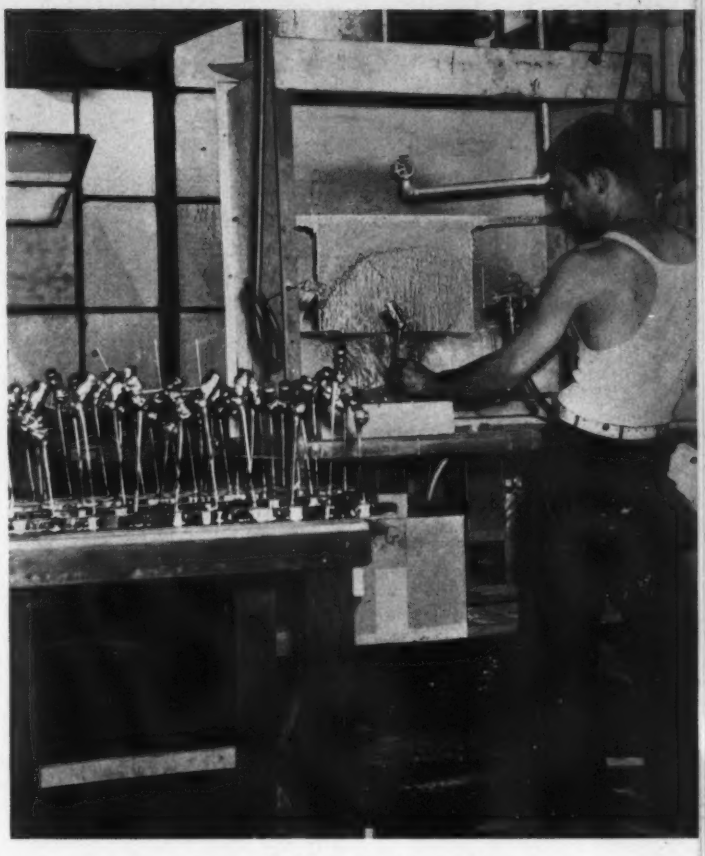


Fig. 5. Dopey's coating of gold enamel is applied.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING OCTOBER

Glass Containers: Production of glass containers during the month of October, 1938, was 3,865,763 gross, bringing the 1938 total to 35,873,253 gross. Shipments during October were 3,953,514 gross, bringing the 1938 total to 36,844,337 gross.

Plate Glass: The production of polished plate glass by member companies of the Plate Glass Manufacturers of America during October, 1938, was 12,868,717 sq. ft., as compared to 8,873,344 sq. ft. produced in the preceding month, September, and 14,854,918 sq. ft. produced in October, 1937. This makes a total of 60,151,209 sq. ft. produced during the first ten months of 1938.

Window Glass: During October, 1938, the production of window glass was 641,394 boxes, which represents 39.5 per cent of industry capacity. As compared with this, October, 1937, production was 1,185,560 boxes, representing 73.0 per cent of industry capacity.

Chief executives of newly formed Owens-Corning Fiberglas Corporation: Left, Harold Boeschenstein, president, and Amory Houghton, chairman of the board.

BOESCHENSTEIN HEADS NEW FIBERGLAS CORPORATION

With the establishment of general offices in the Second National Bank Building, Toledo, the recently-formed Owens-Corning Fiberglas Corporation is rapidly completing its organization and personnel for the development, manufacture and sale of fiber glass products. Owens-Illinois Glass Co. and Corning Glass Works cooperated in the formation of the new company, which will extend the activities formerly carried on by the parent companies in their plants at Newark, Ohio, and Corning. The president of the new corporation is Harold Boeschenstein, formerly vice-president of Owens-Illinois, and Amory Houghton, president of Corning Glass Works, is chairman of the board. In addition to these, the board of directors will also include C. B. Belknap, U. E. Bowes, G. W. Cole, W. E. Levis and G. D. Macbeth. The new corporation is financed jointly by Owens-Illinois and Corning and is an independent corporate structure. It will not operate as a subsidiary of either parent company.

Owens-Illinois and Corning Glass, working cooperatively on both research and development, have expended a total of about $5,000,000 on the development and manufacture of fiber glass products, including perfection of necessary machinery and processes, all of which are covered by basic patents. The commercial importance of fiber glass arises from its resistance to the action of moisture, chemicals and heat, and it is used in all sorts of textile forms, such as loose fiber, yarn, tape and cloth. Successful applications include heat insulation for ovens, refrigerators and piping; electrical insulation for motors and other electrical equipment; building insulation; mulch for plants and shrubs; air filters; chemical filters; and storage battery separator plates.

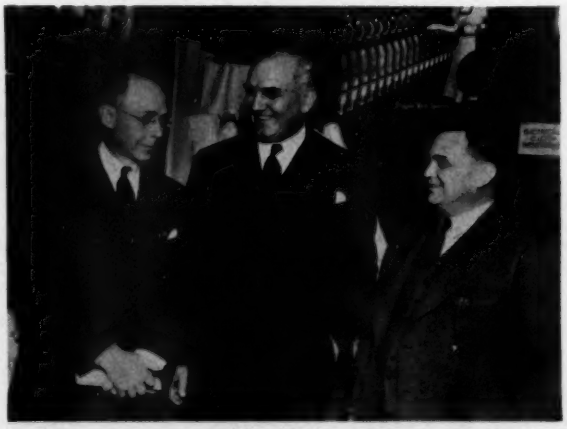
Other officials of Owens-Corning Fiberglas Corporation are Games Slayter, vice-president, who is credited with a major role in the development of this new product; W. B. Zimmerman, vice-president in charge of manufacturing and sales, formerly general manager of the industrial products division of Owens-Illinois; G. E. Gregory, general sales manager, formerly sales manager of fiber products at Corning; A. C. Freligh, secretary, formerly comptroller of fibre products at Corning; H. R. Winkle, comptroller, former assistant comptroller of Owens-Illinois.

Most of the development and manufacturing activities of the new company will be carried on in the big plant which Owens-Illinois built and equipped at Newark, Ohio. Assisting Mr. Slayter at Newark are J. H. Thomas, manager of research development, and H. C. Bates, manager of product development and experimental sales. The manufacturing activities will be headed by B. E. Boyd, general factory manager, W. M. Bergin, superintendent of wool production, and J. D. Barker, superintendent of textile production.

The sales and administrative officials of the new company are located in the general offices at Toledo. Assistants to Mr. Gregory are R. C. Dodson, sales control; I. A. Rustad, field sales coordination; and Philip Linne, advertising. Product sales managers are H. R. Black, special products; J. S. Irvine, air filters; D. C. Simpson, textiles; and W. C. Wilson, insulation products. J. G. Leisenring functions as operations supervisor and C. G. Staelin heads the legal and patent department.

LEVIS BECOMES O.-I. VICE-PRESIDENT

J. P. Levis, formerly head of the Owens-Illinois Pacific Coast Co., has been named vice-president and general manager of the Owens-Illinois Glass Co., replacing Harold Boeschenstein, who recently resigned to become president of Owens-Corning Fiberglas Corporation. Mr. Levis has also been made a director of Owens-Illinois. His early training was with the Illinois Glass Co. and he was manager of the plant at Alton before going to the Pacific coast subsidiary. Several other executive changes have been made necessary by the resignation of those who have joined the management of the new fiber glass company. The Insulux Products Division takes over the remaining activities of the former Industrial and Structural Products Division, including structural building blocks and Hemingray insulators, and will be headed by S. J. McGiveran as general manager. Hugh Paul has been appointed sales manager of this division. H. S. Wade has been named vice-president and general manager in the Owens-Illinois Pacific Coast Co., replacing Mr. Levis, and R. B. Haworth has become general factories manager for the Western subsidiary.



Three developers of fiber glass. Left to right: Dr. Eugene C. Sullivan, director of research, Corning Glass Works; U. E. Bowes, director of research, Owens-Illinois Glass Co.; and Games Slayter, vice-president of the newly formed Owens-Corning Fiberglas Corporation, who is credited with having played a major part in the development of Fiberglas.

COMPARISON OF THERMAL EXPANSIONS OF GLASSES

By A. E. BADGER and J. F. WHITE*

Thermal expansion is one of the most important physical properties of glass and various types of equipment are available for its measurement. Considerable work has been published on methods of determining thermal expansion and on the results of such measurement. Thermal expansion factors for the various oxides used in glass-melting have been computed from these data.

However, there seems to be no publication dealing with the thermal expansions of glasses containing equivalent amounts of the various oxides which can be incorporated in glass. Therefore, a series of glass was planned in which various oxides would be introduced in a soda-lime-silica glass. The base glass chosen had the chemical composition 17.4 per cent Na_2O, 10.1 per cent CaO, 72.5 per cent SiO_2 (or 1.4 Na_2O : 0.9 CaO : 6.0 SiO_2, on a molal basis).

Additions of various oxides were made to the glass batch corresponding to the above composition, in such amounts that equal numbers of atoms of the various elements were added to the base glass. The actual amounts chosen are given in Table 1, which shows that .03 gram-atom of various elements were incorporated in the base glass of the molal composition given above.

The chemical compositions of the glasses, as computed from the batch, are also listed in Table 1. Although these are not analyzed compositions, they are close to the actual compositions since the batch materials were of chemically-pure grade and the melts were made in platinum containers to maintain their purity.

The determinations of thermal expansion were made by means of an interferometer type of apparatus. The expansion curves are shown in Fig. 1 (a), (b), (c), (d), (e), which may be used to determine the coefficient of expansion over any desired range of temperature. Table 1 lists the average cofficients of thermal expansion from 30 to 300° C, and also the comparative softening temperatures of the glasses. The latter are the temperatures at which the glass samples show contraction in the furnace. These temperatures can be checked to within 3° C. The expansion coefficients are accurate to about one per cent.

Fig. 1 (a) illustrates the effect on thermal expansion of additions of the alkalis. Glass No. 1 refers to the base soda-lime-silica glass, while Nos. 5, 6, and 7 show the effects produced by additions of equivalent amounts of lithium, sodium, and potassium atoms, respectively. Fig. 1 (b) gives the expansion curves of glasses with equivalent additions of MgO, CaO, BaO, ZnO, and PbO (Nos. 8, 9, 10, 11, 15, respectively). Fig. 1 (c) shows similar data for glasses containing B_2O_3, Al_2O_3, or V_2O_5 (Nos. 12, 13, and 41, respectively), while Fig. 1 (d) refers to glasses with iron, cobalt, nickel, or manganese oxides (Nos. 16, 17, 18, and 19). Fig. 1 (e) applies to the glasses made with additions of SiO_2, TiO_2, ZrO_2, or CeO_2 (Nos. 14, 39, 42, and 43).

The expansion coefficients and softening temperatures which are listed in Table 1 are illustrated graphically in Fig. 2. This figure shows the changes in the coefficient

TABLE I

CHEMICAL COMPOSITIONS OF GLASSES.

Thermal Expansion Coefficients, and Softening Temperatures.

(The base glass was 1.4 Na_2O:09 CaO:6.0 SiO_2 or 17.4% Na_2O, 10.1% CaO, 72.5% SiO_2, with additions of various materials were made in accordance with Table I)

Glass No.	*Substance Added to Base glass (mol)*	*Chemical Composition (%)* SiO_2	Na_2O	CaO	*Additional Substance*	*Mean Coef. of Expansion to 300°C. ($x10^7$)*	*Softening temp., °C.*
1	None	72.5	17.4	10.1	0	102	585
5	0.015 Li_2CO_3	71.6	17.2	9.9	1.3 Li_2O	108	535
6	.015 Na_2CO_3	70.6	16.9	9.8	2.7 Na_2O	117	590
7	.015 K_2CO_3	69.6	16.7	9.6	4.1 K_2O	110	540
8	.030 Mgo	70.0	16.8	9.7	3.5 MgO	104	580
9	.030 $CaCO_3$	69.0	16.6	9.6	4.8 CaO	103	600
10	.030 $BaCO_3$	63.7	15.3	8.9	12.1 BaO	108	570
11	.030 ZnO	67.6	16.2	9.4	6.8 ZnO	100	560
12	.015 B_2O_3	70.3	16.9	9.7	3.1 B_2O_3	98	565
13	.015 Al_2O_3	69.4	16.6	9.6	4.4 Al_2O_3	97	595
14	.030 SiO_2	68.8	16.5	9.6	5.1 SiO_2	99	590
15	.010 Pb_3O_4	60.4	14.5	8.4	16.7 PbO	120	475
16	.015 Fe_2O_3	67.7	16.2	9.4	6.7 Fe_2O_3	105	565
17	.010 Co_3O_4	68.0	16.3	9.4	6.3 CoO	101	565
18	.015 Ni_2O_3	68.0	16.3	9.4	6.3 NiO	103	580
19	.030 MnO_2	67.7	16.3	9.4	6.6 Mn_2O_3	110	570
39	.030 TiO_2	67.7	16.2	9.4	6.7 TiO_2	97	585
41	.015 V_2O_5	67.1	16.1	9.3	7.5 V_2O_5	108	540
42	.030 ZrO_2	65.3	15.7	9.0	10.0 ZrO_2	93	655
43	.030 CeO_2	62.8	15.1	8.7	13.4 CeO_2	99	595

Fig. 1. Thermal expansion curves of glasses. The percentage thermal expansion of the glasses is plotted against the temperature.

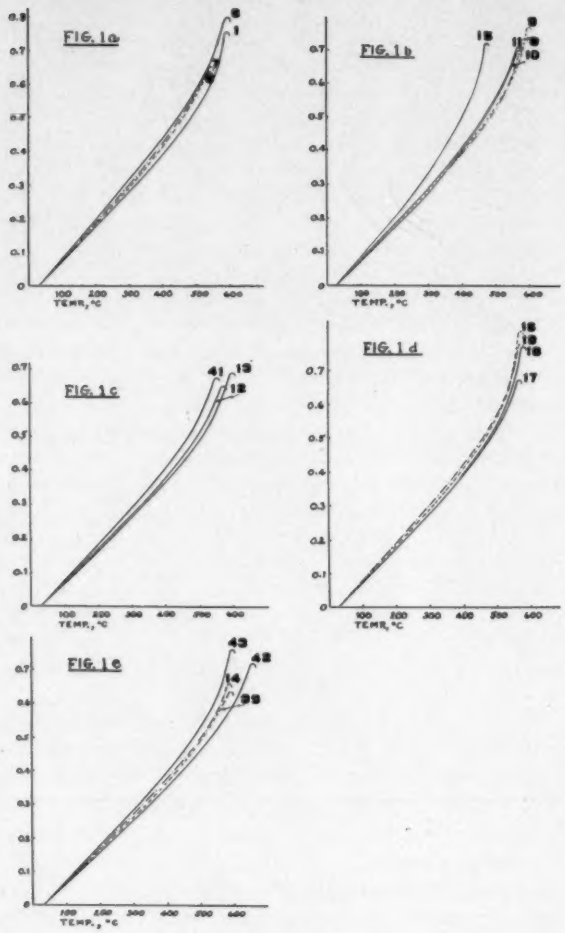
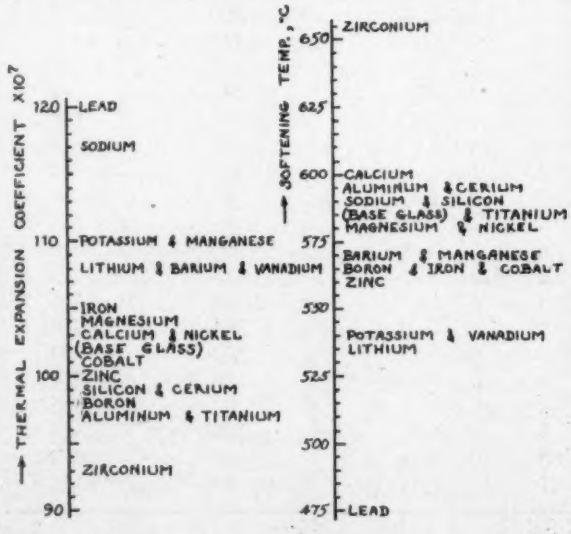


Fig. 2. Graphic representation of the expansion coefficients and softening temperatures listed in Table I.



of thermal expansion (30 to 300° C) which are produced by adding equivalent amounts of various elements (.03 gram-atom in this case) in the form of their oxides to the base soda-lime-silica composition.

The thermal expansion coefficients which are shown on the graph in Fig. 2 apply to glasses which contain varying percentages of additional oxides, although the equivalent weights of added materials are all equal. If thermal expansion factors on a weight percentage basis are calculated from the experimentally determined expansions and from the calculated chemical analyses of the glasses, an expansion series may be arranged to show the relative effects of adding equal percentages of the various oxides to these glasses. This series is in the following order, where the oxide producing the greatest expansion is first in order, each succeeding oxide producing a smaller expansion than those preceding: oxides of lithium, sodium, potassium, mangenese, lead, vanadium, magnesium, barium, iron, calcium, nickel, cobalt, cerium, zinc, silicon, titanium, zirconium, aluminum, boron. This series has a restricted use in that it applies only to the glass compositions studied here.

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NIELSEN SAILS FOR COPENHAGEN

Carl A. Nielsen has sailed for Denmark to become plant manager of the Holmesgaards Glasvaerk in Copenhagen. Mr. Nielsen was formerly associated with the Amsler-Morton Co., and since 1934 has been with the Owens-Illinois Glass Co. as a mechanical engineer in their Alton, Ill., plant. The Holmesgaard Glasvaerk formerly was noted for its production of art glass, but four years ago built a new factory for the fully automatic production of bottles.

BATTELLE INSTITUTE APPOINTS

Earle C. Derby, newly elected president of the board of the Battelle Memorial Institute, industrial research organization of Columbus, Ohio, has announced the appointment of Rolland C. Allen, vice-president of Oglebay, Norton & Co., as a member of the board of trustees. Mr. Allen's appointment, filling the vacancy created by the death of Joseph H. Frantz, late president of the board, brings to the Institute the services of an executive with wide experience in scientific, governmental and industrial organizations.

Another appointment to the Institute is that of Walter C. Rueckel, who has joined the staff as research engineer, according to an announcement by Clyde E. Williams, director. Dr. Rueckel, who has been with the Koppers Co. for the past three years, will be engaged in ceramic research, a field in which Battelle is particularly active.

AIR FILTER RESEARCH AT MELLON INSTITUTE

Dr. Edward R. Weidlin, Director, Mellon Institute, Pittsburgh, has announced the establishment of an Industrial Fellowship in that institution by the American Air Filter Company, Inc., of Louisville, Ky. This Fellowship will investigate broadly materials of value in the construction of filters for air-conditioning systems. Dr. Frank F. Rupert, who has been appointed to the incumbency of the Fellowship, has been a member of Mellon Institute since 1913.

OPTICAL GLASSES

By DR. OSCAR KNAPP, Ujpest, Hungary

IT is usual in the technical world to call the products which are valuable, rare or very expensive precious, rare or rich ones. Thus, we know precious stones, rare gases, rich ores. If we classify the various products of the glass industry according to their quality and value, the optical glasses must be regarded as precious glasses. This statement may be proved by the fact that, according to the price list of a German firm, one optical objective disc in 100-cm. diameter and in 11-cm. thickness costs about $120,000. Should such a disc serve as an astronomical mirror disc, its price would be about $220,000. These high prices are justified by accurate chemical and physical qualities, to which qualities of no other glasses can be compared.

People are sometimes apt to consider glasses for spectacles, condenser lenses, and mirrors as optical glasses. This term is, however, not correct for these glasses, because only glasses for optical scientific instruments with given optical data and special chemical composition, with high homogeneity can be regarded as optical glasses.

The duty of optical glass is to divert the direction of white light rays without chromatism. For example, if white light rays fall on a glass prism, the rays with different wave lengths deviate from the original direction in different measure, and instead of the broken white light there appear the colors of the rainbow. If we put another prism with corresponding refraction angle in a turned position beside the first prism, it gathers the spectrum again to white light. This white light is, however, only approximately white. Using even a prism pair, which unites the blue and red waves, we do not get a perfect white, because the other colors are unable to compensate each other and it remains the so-called secondary spectrum. We can get only a perfect white color, achromatism, if the partial dispersion of both the glass prisms is the same. In case of the astronomical telescopes only that chromatic defect occurs.

In the case of terrestrial optical instruments, i.e., microscope, photographic camera, there appear in consequence of the qualities of the glass two other defects. Astigmatism causes the defect, that on the field of view a dot appears as two lines vertical on each other. Due to the other defect, aberration, the figure of the object appears not in a level plan, but on a concave one.

The opticians and mathematicians had already found in the middle of the past century the conditions for eliminating these defects, and fixed the qualities with which optical glasses are to be furnished. These conditions were summarized by Abbe as follows:

Glasses should be melted, which have lower partial dispersions or higher refraction with the same dispersion than the common glasses. Furthermore, the rate of the relative dispersion of the flint glasses must be the same or very similar to that of crown glasses, and the dispersion of the flint glasses has to be great at medium refraction.

The qualities of the optical glasses are characterized by two factors, i.e., refraction and dispersion. The refractive index is the relation of the sines of the incident and refracted rays. The measure of the mean dispersion is the difference of the refractive indices for the red and blue spectral colors. Both qualities are simultaneously expressed by the Abbe-value γ, which gives the relation of the refractive index based on helium light, minus one, to the mean dispersion. The optical position of the optical glasses is given by the refractive index, the mean dispersion and the Abbe-value.

Till the last century, the glass industry endeavored unsuccessfully to find the solution of the problem of melting glasses furnished with the requested conditions, from the raw materials known at that time. The glasses composed of the classical oxides, i.e., silica, calcium oxide, magnesium oxide, potassium oxide, sodium oxide and alumina follow some special law. The glasses melted from these oxides have refraction and dispersion showing precise linear regularity. These glasses cannot be free from optical defects, and were unfit for making suitable lenses for telescopes, microscopes or cameras. The problem of making good optical glasses was solved by Schott and Abbe, who melted glasses with new and, at that time, unusual oxides. Due to the painstaking work of these two pioneers and other experts in several countries, the optical glass industry has supplied the makers of optical apparatus with new and ever-improving optical glasses.

The optical glasses must fulfill several chemical requirements, which must be taken into consideration in their melting. These requirements are as follows:

1. The glass composition must insure the required optical position, i,e., the refraction and the dispersion, which values must be precisely constant for every melt of every glass.

2. The batch must deliver at normal furnace conditions an easily meltable glass of sufficiently low viscosity.

3. The glass should not devitrify, even upon long annealing.

4. It must be, even in large pieces, so far as possible, colorless, without using decolorizing agents such as manganese dioxide or selenium. In some glasses with high lead oxide content, a yellowish tint is unavoidable.

5. The properties respecting grinding and polishing of the glasses must be advantageous.

6. It must be durable to withstand the action of the atmosphere and maintain its surface undimmed after long usage and under all climatic conditions. In some cases, however, when extreme optical values are required, it is possible to melt glasses with only poor durability and to protect them by durable, optically neutral glasses.

7. The glass must be free of bubbles.

The nomenclature and designation of optical glasses varies among the manufacturers. Some factories name the glasses according to their chemical composition and by current numbers; e.g., BaLF 3 means Barium, Light Flint 3. Another glassworks uses the numbers of the first meltings. An optical glassworks uses both designation, e.g., DBC5728 means Dense Barium Crown melt number 5728. One optical glassworks names its glasses in a way which is correct and logical. Every glass is characterized by a fraction, the numerator of which is the refractive index expressed by three numbers after

the decimal point, and the denominator the first three numbers of the Abbe-value. Thus the glass 609/589 denotes that the refractive index of this glass is 1.609 and the Abbe-value 58.9. In the following description the nomenclature of the optical glasses is based on the chemical composition and on their optical data. The classification arranges itself according to the graph on page 467, in which the ordinate gives the refractive indices for helium light and the abscissa the Abbe-values. According to this classification, we know the following classes of the optical glasses:

I. Crown glasses, the Abbe-values of which are more than 55.0.

II. Transition glasses, the Abbe-values of which vary between 50.0 and 55.0.

III. Flint glasses with Abbe-values below 50.0.

Crown glasses are divided in the following groups:

1. Fluorite Crown, FC.
2. Phosphate Crown, PC.
3. Dense Phosphate Crown, DPC.
4. Borate Crown, BC.
5. Crown, C.
6. Medium Barium Crown, MBaC.
7. Dense Barium Crown, DBaC.

The transition glasses are divided in the following groups:

8. Crown Flint, CF.
9. Light Barium Flint, LBaF.
10. Extra-Dense Barium Crown, EDBaC.

The Flint glasses contain groups as follows:

11. Extra-Light Flint, ELF.
12. Barium Flint, BaF.
13. Light Flint, LF.
14. Flint, F.
15. Dense Barium Flint, DBaF.
16. Dense Flint, DF.
17. Extra-Dense Flint, EDF.

In addition to these given groups there are some optical glasses which cannot be incorporated in the graph, because their chemical composition and optical data are not in agreement. These glasses comprise the group of: 18. Special glasses, S.

In each group, except the last one, the chemical compositions of the glasses are very similar and only the quantity of the characteristic glass oxides is more or less different. In some cases some other oxides are present as minor constituents. The little changes in the chemical composition make possible the melting of glasses, which belong in the same group having, however, different optical position.

The group in which the optical glasses possess the lowest refraction and the highest dispersion, is the group of Fluorite Crown, noted as FC. The limit of refractive index in this group is 1.46 and 1.48, that of the Abbe-value 65.0 and 71.0 and the mean dispersion varies between 0.0069 and 0.00726. These glasses contain fluorine as a characteristic constituent. The chemical composition of one of these Fluorite Crowns follows:

TABLE 1—FLUORITE CROWN GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	K_2O	F
FC 471/672	53.3	16.2	8.8.	16.2	5.3

The next group contains the Phosphate Crown glasses, noted as PC. These glasses have their refractive indices between 1.49 and 1.54, the Abbe-values between 64.0 and 70.0 and mean dispersion between 0.0070 and 0.0084. The glasses of this group are characterized by their phosphorus content, by which the silica is entirely replaced.

TABLE 2—PHOSPHATE CROWN GLASSES

Glass	P_2O_5	B_2O_3	Al_2O_3	As_2O_3	MgO	K_2O
PC 516/700	70.5	3.0	10.0	..	4.0	12.0
PC 522/697	69.5	3.0	10.0	1.5	4.0	12.0

The Dense Phosphate Crown glasses have refractive indices above 1.54, the same Abbe-values as the glasses of the previous group and mean dispersion between 0.0084 and 0.0092. They are characterized by the absence of alkalies and by a relative high amount of Barium. Some of these glasses are shown in Table 3.

TABLE 3—DENSE PHOSPHATE CROWN GLASSES

Glass	P_2O_5	B_2O_3	Al_2O_3	As_2O_3	BaO
DPC 562/665	59.5	3.0	8.0	1.5	28.0
DPC 567/656	56.0	3.0	1.5	1.5	38.0
DPC 576/652	54.0	3.0	1.5	1.5	40.0
DPC 591/641	50.0	3.0	..	2.0	45.0

The Borate Crown glasses have same refractive indices, 1.49-1.54, their Abbe-values lie between 62 and 67 and mean dispersion between 0.0073 and 0.0087. The characteristic constituent of these glasses is boric oxide, 5-15 per cent. Its composition is summarized in Table 4.

TABLE 4—BORATE CROWN GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	CaO	BaO	ZnO	Na_2O	K_2O
BC 510/634	70.4	7.5	..	2.0	..	..	5.3	14.5
BC 507/620	70.6	6.0	1.0	..	..	..	11.5	10.5
BC 498/652	71.0	14.0	5.0	..	..	..	10.0	...
BC 516/640	69.6	9.9	..	..	2.5	..	8.4	8.4
BC 513/637	68.3	10.0	..	..	..	2.0	10.0	9.5

The Crown glasses lie between refractive index 1.50 and 1.54, Abbe-value 55 and 62 and have mean dispersion between 0.0081 and 0.0087. According to their chemical composition they are divided into three undergroups: Light Barium Crowns LBaC, common Crowns C and Zinc Crowns ZnC.

TABLE 5—CROWN GLASSES

Glass	SiO_2	B_2O_3	CaO	BaO	ZnO	PbO	Na_2O	K_2O
LBaC 518/604	68.5	3.5	..	9.7	1.0	..	12.0	5.0
C 515/566	69.2	..	4.0	..	..	6.5	3.0	17.0
C 501/602	74.6	..	5.0	..	..	..	9.0	11.0
C 511/605	68.1	3.5	..	..	7.0	..	5.0	16.0
C 518/602	64.6	2.7	..	10.2	2.0	..	5.0	15.0
C 517/609	69.0	2.5	8.0	..	..	..	4.0	16.0
ZnC 518/602	65.6	4.5	..	..	11.5	..	14.5	3.5
ZnC 513/573	70.6	..	..	..	12.0	..	17.0	..

The following group contains the Medium Barium Crown glasses, with refractive indices between 1.54-1.59, Abbe-values of 55-62 and mean dispersion of 0.0095-0.0102. The glasses have as characteristic oxide, barium oxide up to about 30 per cent. The compositions are shown in Table 6.

TABLE 6—MEDIUM BARIUM CROWN GLASSES

Glass	SiO_2	B_2O_3	BaO	ZnO	PbO	Na_2O	K_2O
MBaC 573/575	48.8	3.7	28.9	10.0	..	1.0	7.4
MBaC 541/596	59.5	3.0	19.2	5.0	..	3.0	10.0
MBaC 570/560	49.9	6.0	20.3	11.4	3.1	5.0	5.0
MBaC 556/586	56.0	..	8.5	2.0	18.1	2.0	13.0

The Dense Barium Crown glasses differ from glasses of the foregoing group in having higher values of refractive indices for the same Abbe-values. The refractive index of these glasses reaches about 1.62. The mean dispersion lies between 0.0093 and 0.0102. The characteristic constituent of these alkali-free glasses is barium oxide in amounts above 40 per cent, as in Table 7.

TABLE 7—DENSE BARIUM CROWN GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	As_2O_3	BaO	ZnO	PbO
DBaC 609/566	34.5	10.2	5.0	..	42.0	7.8	..
DBaC 610/588	31.0	12.0	8.0	1.0	48.0	..	..
DBaC 589/613	37.5	15.0	5.0	1.5	41.0	..	..
DBaC 610/567	39.5	6.5	2.5	..	42.0	9.0	..
DBaC 610/557	39.6	6.0	3.0	..	40.5	8.8	1.6
DBaC 622/570	30.4	11.2	5.2	..	48.6	2.6	..

The Crown-Flint glasses occupy the field limited by the refraction value 1.51-1.54 and Abbe-value 50-55. The mean dispersion varies from 0.0094 to 0.0106. Glasses of this group contain in addition less than 20 per cent of the components of the common lead oxide glasses. One glass in this group has a very strange chemical composition with a relative high antimony oxide content. The glasses, according to their chemical and optical data, are summed up in Table 8.

TABLE 8—CROWN FLINT GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	Sb_2O_3	CaO	ZnO	PbO	Na_2O	K_2O
CF 536/511	63.0	1.8	..	..	2.0	..	16.0	6.0	11.0
CF 523/515	68.3	..	0.9	..	..	2.9	12.4	15.5	..
CF 516/536	53.5	20.0	..	20.0	..	..	..	..	6.5
CF 545/503	32.7	31.0	7.0	..	..	..	25.0	1.0	3.0

The Light Barium Flint glasses have the same Abbe-value as the previously mentioned glasses; their refraction is, however, greater and they show indices between 1.55 and 1.60 for a mean dispersion of 0.0102-0.0112. These glasses owe their optical properties to the simultaneous presence of baryta and lead oxide accompanied by zinc oxide. Table 9 shows the composition of this group.

TABLE 9—LIGHT BARIUM FLINT GLASSES

Glass	SiO_2	B_2O_3	CaO	BaO	ZnO	PbO	Na_2O	K_2O
LBaF 563/508	53.5	..	..	14.2	10.0	11.0	1.5	9.5
LBaF 572/504	51.7	..	..	20.0	7.0	10.0	1.5	9.5
LBaF 569/529	51.2	..	..	20.0	14.0	4.0	5.5	5.0
LBaF 580/538	48.8	3.0	..	21.0	15.5	4.1	0.8	6.5
LBaF 550/533	56.2	..	..	15.0	8.2	7.7	1.5	11.0

The Extra-Dense Crown glasses have for the same Abbe-values as both previous groups, the highest refractive values, above 1.60. The mean dispersion is between 0.0114 and 0.0120. The optical position of these glasses is assured by the presence of zinc and lead oxide and of a very high amount of baryta, namely, above 40 per cent. The composition of such a glass is given in Table 10.

TABLE 10—EXTRA-DENSE CROWN GLASS

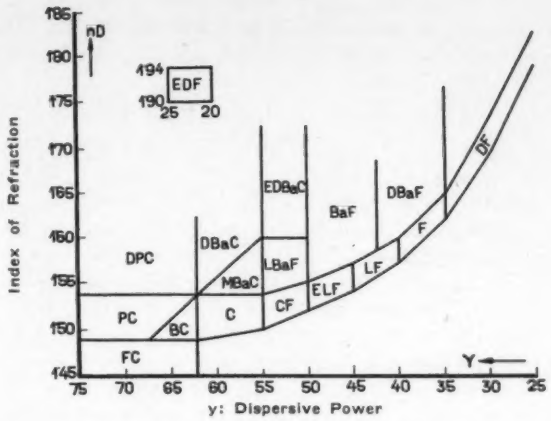
Glass	SiO_2	B_2O_3	Al_2O_3	BaO	PbO	ZnO
EDC 622/532	36.5	6.7	3.0	41.0	5.5	6.8

The first representative group of the Flint glasses are the Extra-Light Flint glasses. The limit of refractive indices is here 1.54-1.57, the Abbe-value 45-50; and the mean dispersion varies from 0.0115 to 0.0124. These glasses are alkali-lead silicates, in which lead oxide takes part up to 30 per cent. One of these glasses is composed in a very interesting way, in that the silica is substituted in half the amount by boric oxide, and the glass is very poor in alkali. In consequence of a high alumina content, this glass is durable in a high degree. The compositions of these glasses are given in Table 11.

TABLE 11—EXTRA-LIGHT FLINT GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	PbO	Na_2O	K_2O
ELF 554/450	59.0	...	...	25.7	4.5	8.0
ELF 541/469	62.7	...	...	23.9	4.5	8.3
ELF 568/467	29.0	29.0	10.0	30.0	1.5	0.5

The Barium Flint glasses have nearly the same Abbe-value, namely, 42.5-50, with higher refraction. The mean dispersion is between 0.0115 and 0.0138. The increase of the refraction above 1.60 is obtained by means of baryta, about 10-20 per cent of which is present in these glasses. The flint characteristic of the glasses is preserved by the presence of lead oxide in the amount of 10-25 per cent. This group is covered in Table 12.



The relationship between the index of refraction and the dispersive power of optical glasses.

TABLE 12—BARIUM FLINT GLASSES

Glass	SiO_2	BaO	ZnO	PbO	Na_2O	K_2O
BaF 556/486	55.9	11.5	..	17.3	2.0	13.0
BaF 570/500	52.4	18.5	5.8	11.2	10.1	1.6
BaF 582/463	49.1	13.0	8.5	19.3	1.0	8.5
BaF 602/439	45.2	16.0	8.3	22.2	...	7.8

The Light Flint glasses, limited by the refractive indices 1.56 and 1.59 and by the Abbe-values 40 and 45, are characterized by lead oxide in the amount of 30-40 per cent. The mean dispersion of these glasses is 0.0133-0.0144. As minor constituents, there may be alumina and boric oxide, as seen in Table 13.

TABLE 13—LIGHT FLINT GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	PbO	Na_2O	K_2O
LF 571/430	54.2	..	1.5	33.0	3.0	8.0
LF 580/410	53.3	0.8	..	33.5	4.0	8.0
LF 575/410	53.7	..	..	36.6	1.0	8.3

The Flint glasses are invested with refractive indices 1.69-1.74 and with Abbe-values 35-40. The mean dispersion is 0.0152-0.0176. These glasses contain nearly the same amount of silica and lead oxide. As minor constituents, alkalies in about 10 per cent are present. The change in the silica and lead oxide content and in the sodium and potassium oxide gives the variation of the optical positions. The glasses are durable, though one of them is subject to spot sensibility and, therefore, becomes dim at the touch of organic acids or sweat. The chemical and optical data are put forth in Table 14.

TABLE 14—FLINT GLASSES

Glass	SiO_2	PbO	Na_2O	K_2O
F 624/359	45.4	45.1	1.5	7.7
F 621/361	45.1	46.4	0.5	8.0
F 614/369	46.4	43.0	1.5	8.8
F 616/366	46.1	45.1	1.7	6.8
F 605/376	46.7	42.0	4.0	5.0

The refraction of the Flint glasses can be increased by incorporating into them baryta as a constituent oxide. We obtain in this way the Dense Barium Flint glasses, the refractive indices of which are 1.60-1.67, the Abbe-values 35-42.5 and the mean dispersion 0.0151-0.0186. The durability against weathering of these glasses is ad-

vantageous, but the spot sensibility is unfavorable. Some of these glasses have a yellowish color due to their high lead oxide contents.

TABLE 15—DENSE BARIUM FLINT GLASSES

Glass	SiO_2	BaO	ZnO	PbO	K_2O	Na_2O
DBaF 627/391	42.8	10.8	5.1	32.6	7.5	0.7
DBaF 660/360	36.8	13.0	5.0	38.3	6.5	..

Among the Dense Flint glasses we find a very high refraction with very low Abbe-values. The refractive index varies between 1.64-1.80, the Abbe-value between 25-35. The mean dispersion is also high and reaches values from 0.0185 to 0.0316. The glasses have lead oxide as a predominant constituent in addition to silica. As minor consituents the alkalies play a role. The glasses are all yellowish and have spot sensibility in a great measure.

TABLE 16—DENSE FLINT GLASSES

Glass	SiO_2	PbO	Na_2O	K_2O
DF 717/295	34.7	61.0	1.5	2.5
DF 754/275	28.4	69.0	...	2.5
DF 645/341	41.7	50.5	0.5	7.0
DF 680/317	38.0	56.8	...	5.0
DF 778/265	28.2	70.0	0.5	1.0

The last group with extreme values, the highest refraction and the lowest Abbe-values, is the Extra-Dense Flint group. The refractive indices in this group are higher than 1.80, the Abbe-value is below 25 and the mean dispersion shows a limit 0.032-0.045. These glasses are alkali-free and have only two components, lead oxide in abundance, and silica. The glasses have a yellowish tint, and suffer from high spot sensibility.

TABLE 17—EXTRA-DENSE FLINT GLASSES

Glass	SiO_2	PbO
EDF 890/223	22.0	78.0
EDF 923/209	21.0	79.0
EDF 963/197	18.0	82.0

The group of special optical glasses comprises glasses which have peculiar chemical compositions and which cannot be ordered in the refraction-dispersion graph. The court glasses, Ct., tend to put an end to the secondary spectrum. The glasses with known composition are alkali-free and are melted of boric oxide, alumina and lead oxide. Other special glasses are composed of oxides which differ from the oxides enumerated above, and do not allow the division in groups known so far.

TABLE 18—SPECIAL OPTICAL GLASSES

Glass	SiO_2	B_2O_3	Al_2O_3	BaO	PbO	Na_2O	K_2O	Li_2O
Ct 613/444	...	49.7	13.0	..	37.0	..	..	..
Ct 629/425	...	46.5	7.5	..	46.0	..	..	..
Ct 666/392	...	42.8	5.0	..	52.0	..	..	..
S 509/604	...	69.1	18.0	4.7	...	8.0	..	..
S 523/614	...	71.8	22.4	..	...	..	..	5.8
S 510/589	63.8	...	18.0	3.5	3.0	8.0	3.5	..

The description of optical glasses would not be complete, if we did not mention Quartz glass, which is the first link in the long chain, which begins with the lowest refractive index of 1.458 as Quartz glass and ends with the highest one of 1.963 as Extra-Dense Flint. The variation of the optical data of the optical glasses known so far including Quartz glass is: in refraction, 1.458-1.963; in Abbe-value, 19.7-70.6; in mean dispersion 0.00675-0.0448.

It is, however, not enough for the production of satisfactory and faultless optical glasses to choose suitable chemical composition and to fulfill the necessary technical requirements by melting. In addition to chemical conditions a high grade of physical homogeneity is very essential. The optical glasses must be uniform in every way. The chemical composition of optical and other glasses may be the same; the optical homogeneity, however, distinguishes optical glasses and other types very sharply.

The hindrances to achieving optical homogeneity are change in the chemical composition due to pot attack, the alteration of the glass melt due to volatilization, the incomplete mixing of the batch and melt and the presence of strains in case of incomplete annealing.

The manufacturing of optical glasses needs, therefore, especially great care and requires much knowledge and skill. Even the choice of the raw materials requires great care. The quality and uniformity of the raw materials needs constant chemical control. It is very important to use materials virtually free from iron. The lowest iron content in the raw materials may be 0.0055 per cent of the glass. In recent times, a way has been found by means of which the sand is purified at high temperature with gases, such as sulphuric acid or chlorine, which volatilize the iron in form of ferric chloride. By this process, the iron content of the batch is diminished to 0.0025 per cent. The melted glass from such a batch has a light absorption of no more than 1.5 per cent per inch thickness, a result which is nearly the limit in this direction.

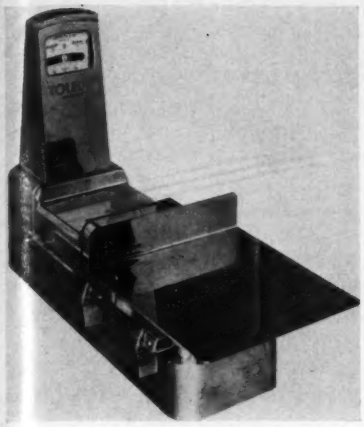
To attain a really excellent homogeneity, it is also necessary to avoid pot attack, which works against the homogeneity in two ways: first, it changes the chemical composition of the glass due to solution of the pot material; secondly, it gives iron to the glass. The effect of the pot attack is diminished by the fact that, contrary to practice in other branches of the glass industry, every pot is used only once. Moreover, research showed, that for melting different types of glasses, different compositions of pot material are necessary. Thus, acidic glasses and borosilicates require pots composed as $Al_2O_3.5SiO_2$. Basic glasses and the Barium Crown glasses on the contrary need pot material, in which the silica is reduced by 10 per cent or more. Another way of eliminating the iron content is, to melt optical glasses only from batch without using cullet. The glass cullet is always richer in iron than the raw materials from which the glass was melted. Thus, if we melt optical glasses without glass cullet from a previous melting, we get a glass with lower light absorption than if we used cullet in the batch. Further developments in the future may be gained by the refractory industry in the manufacturing of pots, which are more insoluble in the glass melt and freer of iron.

To get the desired homogeneity of the melted optical glass it is stirred, whereas other glass melts are not. The success of stirring depends on several conditions: on the velocity of stirrer, on the temperature of the melt, and on the time of stirring. These conditions differ according to the glasses.

After stirring, the pot with the melt is allowed to cool down at a slow rate and is broken up to become large pieces of glass. These pieces are sorted for clearness

(*Continued on page* 471)

EQUIPMENT AND SUPPLIES



TOLEDO SPEEDWEIGH BOTTLE SCALE

The Toledo Scale Co., Toledo, Ohio, has recently brought out a "Speedweigh" scale, especially adapted for the determination of the weight of glass bottles and their contents. As shown in the accompanying illustration, the upper line of the over-and-under scale is graduated to 1/16 of an avoirdupois ounce and the lower line reads in fluid ounces. The beam at the side of the scale has two graduated sections and two poises, the rear section being graduated in avoirdupois ounces and the front section to fluid ounces. The over-and-under charts and the beams are supplemented by weights placed on the rear platter of the scale, so the scale can be used for weighing to a substantial amount in either the avoirdupois or fluid systems. In operation, the empty bottle is first weighed in avoirdupois ounces, thus determining the amount of glass. The bottle is then filled and the additional weight in fluid ounces shows the weight of the contents. The scale provides a rapid and accurate means to control both the glass weight and volumetric capacity of bottles.

BULLETINS RECEIVED

Chas. Taylor Sons Co., Cincinnati. "Taylor Refractories" is an extremely useful and attractively conceived presentation of P. B. Sillimanite and fire clay refractories. It contains specific data on the various items to be considered in purchasing refractories as well as temperature conversion tables, and other information of value.

Chain Belt Co., Milwaukee. Catalog No. 334 contains information on screw conveyor installations, selections of screw conveyors, capacity charts, specifications, etc.

Columbia Alkali Corporation, Barberton, Ohio. A unique feature of the new pocket-size booklet issued by Columbia Alkali is a form of indexing by means of graduated page sizes. It describes the company's complete line including soda ash, caustic soda, liquid chlorine, sodium bicarbonate, calcium chloride and modified sodas.

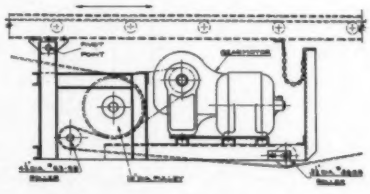
Laclede-Christy Clay Prducts Co., St. Louis, Mo. New glass refractories stock list shows quantities of standard and special blocks and parts ready for immediate shipment at St. Louis and Toledo.

Industrial Gas Engineering Co., Inc., 201 East Erie St., Chicago. A new 54-page illustrated catalogue gives descriptions and engineering data on industrial heating equipment, including high-temperature exhausters, gas and oil fired heating units, and industrial furnaces.

Stephens-Adamson Mfg. Co., Aurora, Ill. Bulletin No. 238 illustrates and describes the "Tellevel" Automatic Storage Control, an automatic electrical device for use on storage bins to control the operation of feeding or discharge conveyors automatically in accordance with the material level in the bin.

MATHEWS BELT-CONVEYOR DRIVING UNIT

A new belt-conveyor driving mechanism, which can be located beneath the conveyor and within the confines of the conveyor framework, is now being marketed by Mathews Conveyor Co., Elwood City, Pa. As shown in the accompanying sketch, the driving motor, together with the main driving pulley and a couple of idler pulleys, is mounted on a suitable frame which is pivoted at one end on the framework of the conveyor. It will be noted that the weight of the driving mechanism is carried on the loose side of the belt, thus making the usual takeup at the end of the conveyor system unnecessary. The manufacturer states that this arrangement provides maximum effective tension with a minimum total belt tension and calls the mechanism a "floating drive." One idler provides a maximum belt wrap around the driving pulley, while the other transmits the weight of the mechanism to the belt and automatically secures the proper take-up and belt tension. The tension varies automatically with the loading of the belt. The new drive is adapted for use on level, inclined or declined conveyors, or combinations of all three. It is available for belt widths from 6 to 30 in.; maximum belt pull up to 500 lb.; and up to 3 h.p. in capacity. The drive is adapted for belt travel in either direction without change and can be used in portable units, if desired. All moving parts of the drive are mounted in ball bearings.

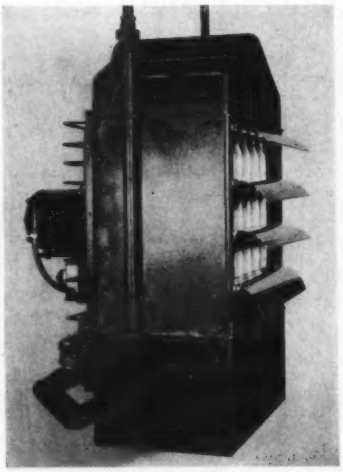


OFFILL TO REPRESENT WALSH

The Walsh Refractories Corporation, St. Louis, Missouri, manufacturers of Vacuum Cast-Flux tank blocks, Missouri super duty, first and second quality fire brick, pot furnace supplies and other refractories used in the glass industry, is now represented in the Western Pennsylvania, Eastern Ohio and West Virginia territory by Paul M. Offill, Jr., 17 Wilmont Avenue, Washington, Pa.

PITTSBURGH GAS-FIRED UNIT HEATER

A recent addition to the line of heating units manufactured by the Automatic Gas Steam Radiator Co., 445 Brushton Ave., Pittsburgh, Pa., is the Pittsburgh, Series U, gas-fired unit heater which operates without steam or water and is completely self-contained. In this unit the gas is fired in a combustion chamber, the products of combustion being passed upward through a bank of tubes and exhausted at the rear of the housing. The heater is designed for ceiling suspension and uses natural or manufactured gas for fuel. A motor-driven fan forces the air over the tubes. The assembly includes a safety pilot. It is stated that the heater may be used for ventilating, cooling and drying, as well as for heating. It is available in five sizes, ranging in heat capacity from 85,000 to 200,000 B.t.u. per hour. Folder No. 552 gives detailed information.



CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 - .0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.0875	.0925
Synthetic (Artificial)	lb.	.0825	.085
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	30.00	....
In bags	ton	31.60	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.076	....
In 5 Ton lots	lb.	....	.08
Less than 5 Tons	lb.	....	.085
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	11.50
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	10.00
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Nepheline Syenite, f. o. b. shipping point	ton	14.50-17.00	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls. 95% and 97%	Per 100 lb.	....	2.50 2.90
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.029	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.07
Antimony oxide (Sb_2O_3)	lb.	.11½	.12¼
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.04¼	.05
Tin Oxide (SnO_2) in bbls.	lb.	....	.50
Titanium Oxide (ceramic grade)			
In bags	lb.	.13¼	.13¼ .14
In barrels	lb.	.13½	.13¾-.14¼
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls.	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .02¼-.02½ higher)		.024	.029

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	.85-.95
Chromite (99% through 200 mesh)	lb.	35.50	40.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.185
Black (CuO)	lb.	....	.16¾-.17¾
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425-.09
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls.	lb.	....	.145
Manganese, Black Oxide			
In Paper bags	ton	54.50	57.50-62.50
In Burlap bags	ton	57.00	60.00-65.00
In Casks	ton	58.50	61.50-66.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09½-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.2075-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08½	.08¾-.08½
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.75-1.80
Yellow	lb.	....	1.75-1.80
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.65-2.75
Yellow orange	lb.	....	1.75-1.80

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¾
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.02
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

OPTICAL GLASSES

(*Continued from page* 468)

and refraction, and range according to these conditions. The clear and good pieces are placed in quadrangular clay molds and are heated in a furnace, the temperature of which is well controlled. The glass pieces become soft and take the form of the mold. These glasses are still full of strains. The presence of strains is, in case of the optical glasses, more dangerous than in other glasses, which need only such degree of elimination of strains, that the glass may be safe against spontaneous fracture. In optical glasses, however, the presence of strains causes different properties and especially different refraction in different directions. Such glass, which is anisotropic and due to the unequal refraction invested with double refraction, is unable to give accurate optical images. Thus, optical glasses must be well annealed.

Though the optician and the physicist can choose in every case the type of optical glass which is best for his purpose—there are still about 120 types of optical glasses—the optical industry uses chiefly the following:

For prisms: BC 510/634 and BC 516/640.

For telescopes and field glasses: BC 510/634, BC 516/640 and BaC 569/560 or BaC 573/575.

For microscope objectives: PC and Ct glasses.

For objective discs: C 518/590, LBaC 518/603 and F 620/363.

For objective discs with diminished secondary spectrum: C 511/606, BC 510/634 and Ct glasses.

For astronomical mirrors: C 518/590, LBaC 518/603, BC 510/634 and BC 516/640.

For photographic objectives: MBaC and DBaC glasses.

GLASS NEWS FROM ABROAD

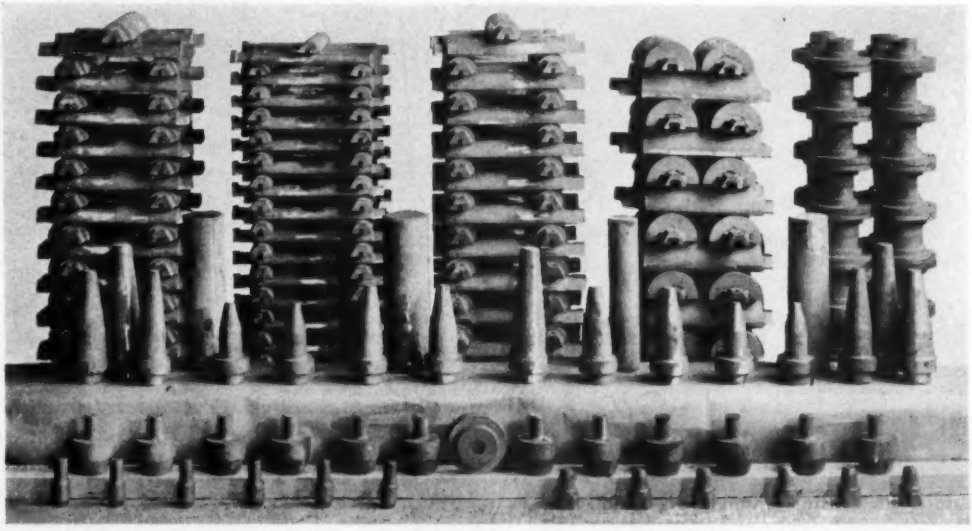
Most important news of the past month on American exports and imports of glass concerned the British Empire and Czechoslovakia. The first concerned primarily our tariff agreements with Canada, which under the most favored nation clause will apply to most other countries.

Glass is not mentioned among our concessions but American glass factories will gain slight advantages:

1. Demi-johns or carboys, bottles, flasks, vials, jars and balls of glass, not cut, n. o. p.; lamp chimneys of glass, n. o. p.; decanters and machine made tumblers of glass not cut or decorated, n. o. p.—27½ per cent, formerly 30 and 32½ per cent.
2. Opal glassware, glass tableware, cut glassware and illuminating glassware, n. o. p.—25 per cent, formerly 27 and 32½ per cent.
3. Manufactures of glass, n. o. p.—17½ per cent, formerly 18 and 22½ per cent.
4. The Canadian treaty also provides that the 3 per cent excise tax on commodities listed in Section 1 be discontinued. Glass is included under this section.
5. There has also been a reduction in duty from 20 per cent to 15 per cent ad valorem for the benefit of exports from the United States of automatic multi-head machines for making glass bottles and glass stems for electric lamps and for exhausting electric lamps and radio tubes.

The question, insofar as to whether Czechoslovakian glass produced in the Sudetenland, now annexed by Germany, would enjoy its former favorable tariff has been settled. It was announced on Nov. 9th that the status of products from the Sudeten area would change from Czechoslovakian to German. Since the United States has no reciprocal agreement with Germany, its products come in at a higher rate. This is particularly important when it is realized that all of the plants producing flat glass and 60 to 70 per cent of the glassware group are included in the ceded territory.

Gunite offers a complete line of castings, plungers, guide rings, round bars and neck ring sticks for use in the glasshouse.



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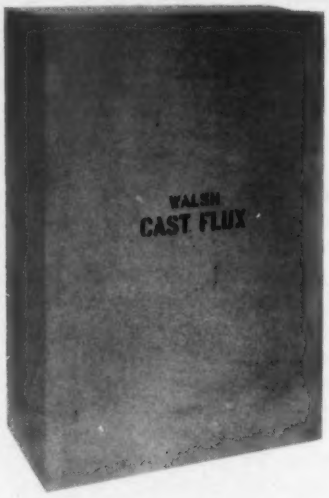
WALSH CAST-FLUX



The Vacuum-cast flux block of superior quality.

Walsh Cast-Flux blocks are machine-trued to exact size and shape after burning.

THEY LAST LONGER

The excellent results obtained in numerous tanks melting various types of glass has definitely established the efficiency and economy of Walsh Cast-Flux blocks.

Walsh Cast-Flux has a dense, uniform structure; it is burned at higher temperatures, is thoroughly bonded and possesses a low coefficient of expansion.

Walsh Cast-Flux blocks meet the most rigid requirements for tanks operating at higher temperatures . . . they insure greater tonnage, higher quality glass, freedom from defects, longer life and maximum economy.

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Manufacturers of Refractories for the glass industry for over 50 years

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MIN-OX
RESISTS SCALE

SPECIALIZED FOR GLASS

Because the alloys used in the manufacture of MIN-OX moulds are the result of metallurgical study directed specifically to the needs of the glass industry, the following advantages are obtained:

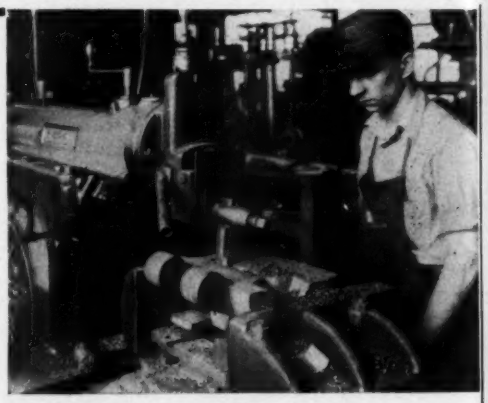
- greater brilliancy is given glassware
- greater fidelity in intricate mould work
- greater economy in manufacture since fire-finishing is eliminated
- reduces cleaning costs
- less spoiled ware
- longer mould life.

We will be glad to tell you how MIN-OX moulds will contribute greater efficiency to the glass plant.

THE BINNEY CASTINGS COMPANY

TOLEDO, OHIO

originators of alloys for glass molds



Machining the face of a section for a bottle mould.

- **The production of moulds for glass manufacturing is a task in which high grade workmanship is combined with first-class equipment.**

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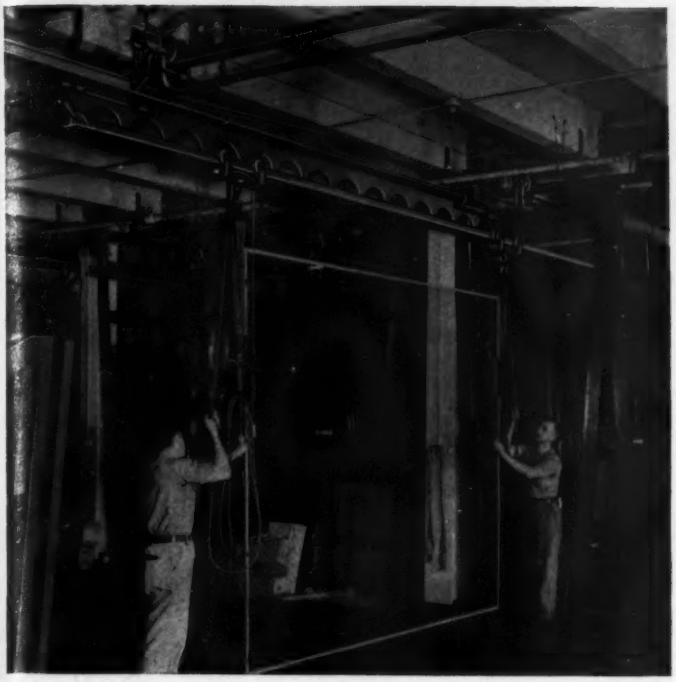

• Cleveland Tramrail, in addition to serving the Glass Industry for accumulation and conveying to the mixers and from the mixers to the furnace, is useful for

Product handling

Through certain other phases of production

For storage

For shipping

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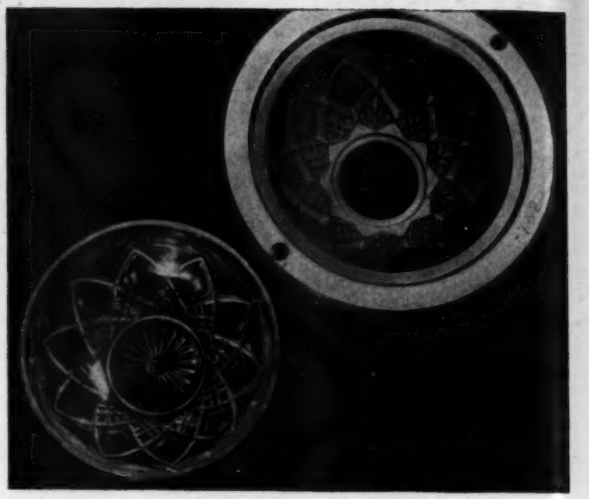

Gortons save time on fancy molds

The tool room can save a great deal of time on glass molds with repetitive patterns by putting them on a Gorton Duplicator. Take the glass dish shown above with its mold. Only enough of the pattern to serve as a model of the design need be cut by tooling out. The whole mold can then be reproduced from this partial model by placing it in an indexing fixture on the Duplicator. This mold was cut on an 8-½-D Duplicator in 26 hours complete. The glass dish is 8″ diam. and 3″ deep. Gorton single flute cutters run at high speeds left a smooth finish remarkably free from tool marks.

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More than 99.50% Sodium Carbonate (on a dry basis).

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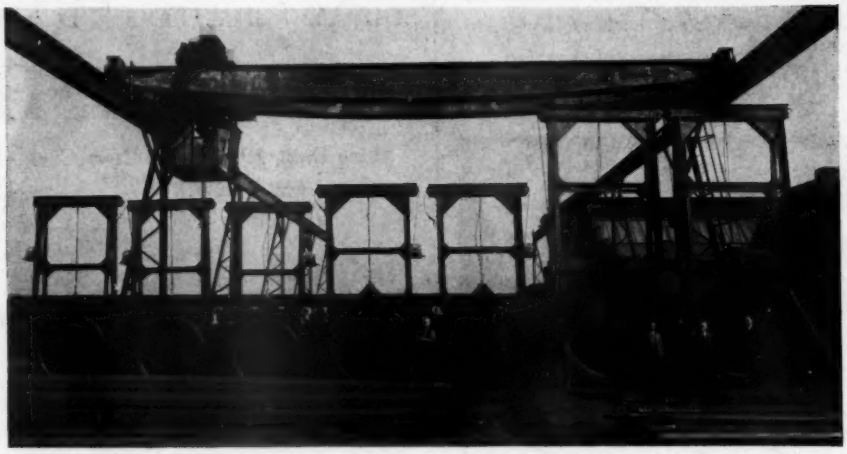

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